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Indian Standard

METHOD OF MEASUREMENT OF NON-LINEARITY IN RESISTORS

UDC 621·316·8·018·783 : 621·317·353

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BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

September 1992 **Price Group 4**

Resistors Sectional Committee, LTD 14

NATIONAL FOREWORD

This Indian Standard, which is identical with IEC Pub 440 (1973) 'Method of measurement of non-linearity in resistors', issued by the International Electrotechnical Commission was adopted by the Bureau of Indain Standards on the recommendation of the Resistors Sectional Committee and approval of the Electronics and Telecommunication Division Council.

Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

Only the English language text in the International Standard has been retained while adopting it in this Indian Standard.

Indian Standard

METHOD OF MEASUREMENT OF NON-LINEARITY IN RESISTORS

1. Scope

The method of measurement of non-linearity described in this report is applicable to resistors. This method is only intended to be used when agreed upon between manufacturer and customer.

2. Object

The object of this report is to standardize a method of measurement and associated test conditions for determining the magnitude of non-linear distortion generated in a resistor.

Limiting values of the magnitude of non-linear distortion for acceptable performance are not specified in this report but should be agreed upon between manufacturer and customer.

3. Measuring principle

A pure sinusoidal current is passed through the component under study. If the impedance of the component is not perfectly linear, the voltage across the component will be distorted and contain harmonics. One or more of these harmonics can be measured and the magnitude of these harmonics is a measure of the non-linearity in the component.

It is recommended to measure the third harmonic. The component may be represented by a linear impedance having a zero-impedance harmonic generator in series.

4. Non-linearity measurement system

When measuring the third harmonic voltage appearing across a component, it must be separated from the fundamental voltage and from all other harmonics. This can be done in different ways.

One method is to use a bridge which is balanced at the fundamental frequency, and the harmonics appear across the bridge diagonal. This method is unfortunately rather time-consuming as the bridge has to be balanced for each test specimen.

The test method chosen here is a filter circuit which is more convenient to use though it puts more stringent requirements on the components making up the circuit.

4.1 *Range of resistance values*

The measuring circuit is suitable for measurements on resistors with resistance values between 1 Ω and 10 MΩ. It may be used for measurements on resistors with values outside these limits, but limited by the overriding influence of the correcting term Δ at high values.

4.2 *Measuring circuit*

A suitable fundamental frequency range for measurements on resistors is between 10 kHz and 40 kHz. This frequency range enables the test circuit to be set up without too much difficulty. Figure 1 shows a block schematic of the test arrangement.

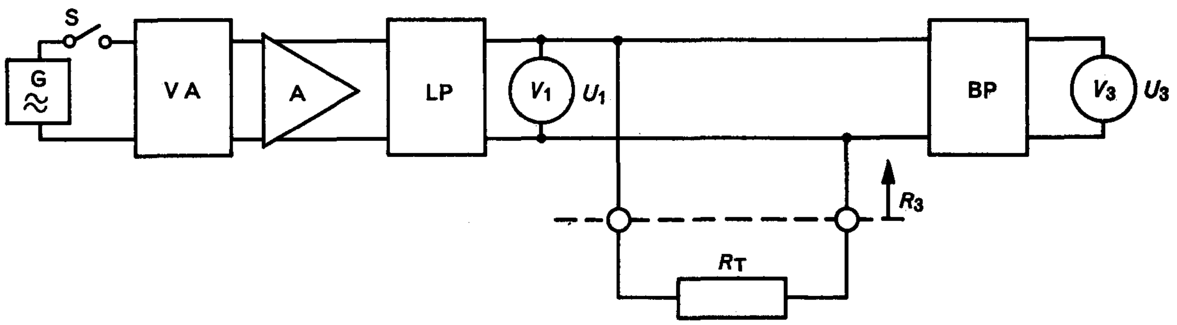

FIG. 1. — Block schematic of test arrangement.

G	Oscillator, fundamental frequency
S	Switch for applying the test signal to the test specimen
VA	Variable attenuator
A	Power amplifier with low distortion
LP	Low-pass filter with cut-off immediately above the fundamental frequency
V_1	Voltmeter to measure the fundamental voltage U_1
BP	Band-pass filter for the third harmonic, with very high attenuation at the fundamental frequency
V_3	Voltmeter to measure voltage U_3 at the third harmonic frequency
R_T	Resistor under test
R_3	Impedance (resistive) seen from the test terminals at the third harmonic frequency.

Note. — A distortion-free impedance matching device can be used to switch R_3 to get good matching to the test specimen R_T (see Table I, page 15). Examples of suitable values of R_3 are 10 Ω, 100 Ω, 1 000 Ω, 10 000 Ω and 100 000 Ω, which values are used for specifying the test conditions in Table I.

4.3 *Equivalent circuits*

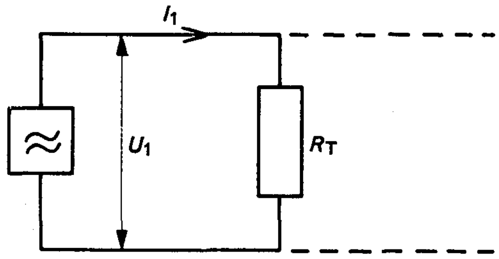

FIG. 2. — Equivalent circuit at the fundamental frequency.

R_T	Impedance of the resistor under test at the fundamental frequency
U_1	Fundamental voltage across the resistor under test

The current I_1 is sinusoidal.

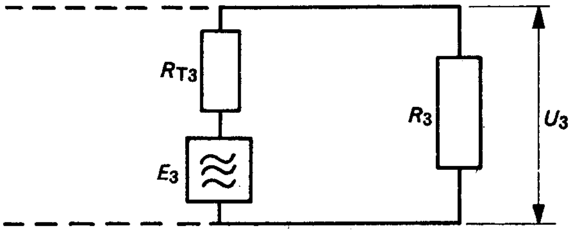

FIG. 3. — Equivalent circuit at the third harmonic frequency.

R_{T3}	Impedance of the resistor under test at the third harmonic frequency
R_3	Impedance (resistive) at the third harmonic frequency, seen from the test terminals (see Table I).

4.4 *Attenuation at the third harmonic frequency*

The e.m.f. of the third harmonic in the component is

$$E_3 = \left| 1 + \frac{R_{T3}}{R_3} \right| U_3 \tag{4.1}$$

The third harmonic attenuation in decibels will be

$$A_3 = 20 \log_{10} \frac{U_1}{E_3} = 20 \log_{10} \frac{U_1}{U_3} - 20 \log_{10} \left| 1 + \frac{R_{T3}}{R_3} \right| \tag{4.2}$$

The correction term Δ in decibels

$$\Delta = 20 \log_{10} \left| 1 + \frac{R_{T3}}{R_3} \right| \tag{4.3}$$

may be taken from the diagram in Figure 4, page 14.

4.5 *Requirements concerning the measuring system*

Precautions must be taken to avoid non-linear distortion from the components near the test specimen in the low-pass and band-pass filters. The filter inductors for instance must not contain cores of magnetic material.

The noise level referred to the test terminals shall not be higher than 0.2 µV at $R_3 = 1\,000\ \Omega$.

The power amplifier shall be capable of delivering 1 W into a resistive component under test.

With 0.25 VA in a virtually linear component, the attenuation 20 log $\frac{U_1}{U_3}$ shall be higher than 140 dB for most of the impedance range.

The inaccuracy of the fundamental frequency voltmeter shall be less than 5% and that of the third harmonic frequency voltmeter less than 10% at full scale deflection.

For checking the measuring system, the instrument shall be equipped with a standard with known non-linearity.

4.6 *Ambient conditions for testing*

Unless otherwise specified, all tests shall be carried out under standard atmospheric conditions for testing as specified in IEC Publication 68, Basic Environmental Testing Procedures.

4.7 *Special precautions*

Ferromagnetic materials give rise to harmonic distortion and care must be taken to avoid influence from, e.g. iron in the immediate vicinity of the component which can mask component non-linearities especially at high currents.

5. Measurement procedure

a) The resistor to be tested is inserted and the switch S (see Figure 1, page 9) closed.

b) The fundamental test voltage U_1 shall be adjusted to a value chosen from Table I, or some other lower voltage where this is necessary because of limitations of the resistor ratings or of the test equipment (see Note 1).

c) The third harmonic voltage U_3 shall then be read on the voltmeter V_3.

The e.m.f. E_3 of the third harmonic in the resistor can be calculated from the expression (4.1) or the logarithmic correction term $\varDelta$ (4.3) can be found from Figure 4 or Table I. According to equation (4.2), the third harmonic attenuation in decibels will be:

$$A_3 = 20 \log_{10} \frac{U_1}{E_3} = D - 20 \log_{10} U_3 - \varDelta \qquad (5.1)$$

where $D = 20 \log_{10} U_1$ and the correction term $\varDelta$ can be taken from Table I.

Notes 1. — It is possible to estimate the third harmonic voltage corresponding to a higher voltage using the following equation:

$$E_3 = E_3' \times \left(\frac{U_1}{U_1'}\right)^n \qquad (5.2)$$

in which:

E_3' is the third harmonic e.m.f. corresponding to the actual fundamental test voltage U_1'

E_3 is the third harmonic e.m.f. corresponding to the fundamental test voltage U_1

n has a value between 1.5 and 3.5 depending on the type of resistor.

2. — For characterizing the non-linearity in resistors, it is also possible to use a "Third Harmonic Index", expressed in decibels, defined as:

$$20 \log_{10} \frac{E_3}{U_1^n} \qquad (5.3)$$

where E_3 is expressed in µV and U_1 in V.

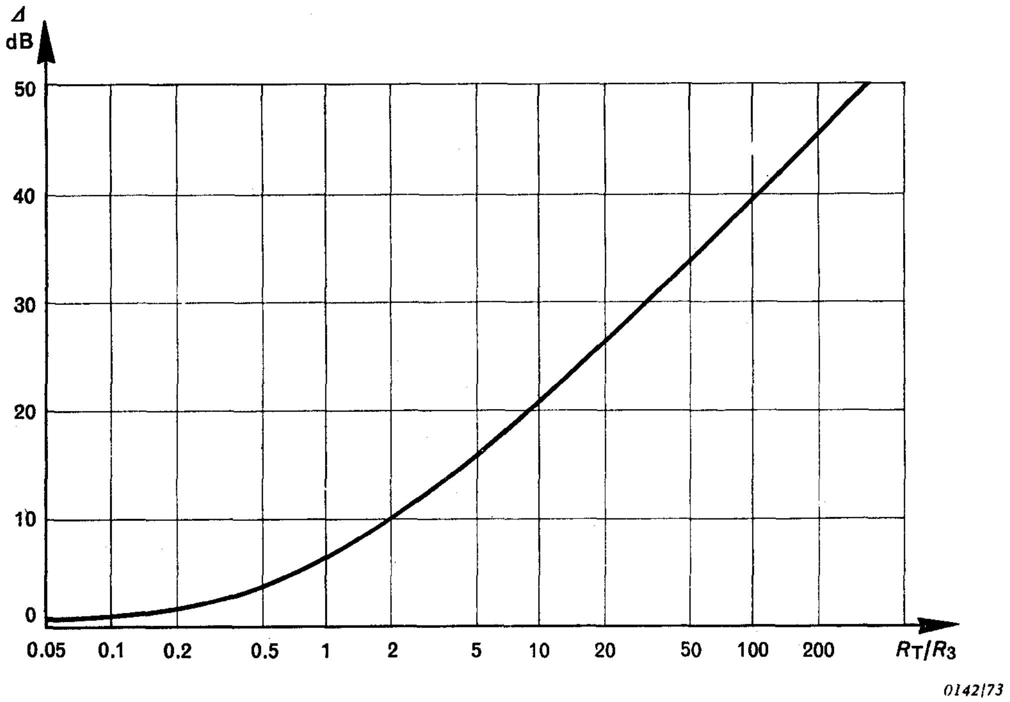

FIG. 4. — Correction term.

$$\Delta = 20 \log_{10} (1 + R_T/R_3) \text{ dB}$$

where:

R_T is the resistance of the resistor under test.

R_3 is the impedance of the measuring instrument at the third harmonic seen from the test terminals.

TABLE I

Recommended operating conditions

		Rated dissipation, *W*							
		≥ 0.25				0.125 & 0.100			
R_s Ω	R_T Ω	U_1 V	*D* dB	*Δ* dB	*P* mW	U_1 V	*D* dB	*Δ* dB	*P* mW
10	1	0.50	−6.0	0.8	250	0.32	−9.9	0.8	100
	1.2	0.55	−5.2	1.0	250	0.35	−9.1	1.0	100
	1.5	0.61	−4.2	1.2	250	0.39	−8.2	1.2	100
	1.8	0.67	−3.4	1.4	250	0.42	−7.5	1.4	100
	2.2	0.74	−2.6	1.7	250	0.47	−6.6	1.7	100
	2.7	0.82	−1.7	2.1	250	0.52	−5.7	2.1	100
	3.3	0.91	−0.8	2.5	250	0.57	−4.9	2.5	100
	3.9	0.99	−0.1	2.9	250	0.62	−4.2	2.9	100
	4.7	1.08	0.7	3.3	250	0.69	−3.3	3.3	100
	5.6	1.18	1.4	3.9	250	0.75	−2.5	3.9	100
	6.8	1.30	2.3	4.5	250	0.82	−1.7	4.5	100
	8.2	1.43	3.1	5.2	250	0.91	−0.8	5.2	100
	10	1.58	4.0	6.0	250	1.00	0.0	6.0	100
	12	1.73	4.8	6.8	250	1.10	0.8	6.8	100
	15	1.94	5.8	8.0	250	1.22	1.7	8.0	100
	18	2.12	6.6	8.9	250	1.34	2.5	8.9	100
	22	2.34	7.4	10.1	250	1.48	3.4	10.1	100
	27	2.60	8.3	11.4	250	1.64	4.3	11.4	100
100	33	2.87	9.2	2.5	250	1.82	5.2	2.5	100
	39	3.12	9.9	2.9	250	1.97	5.9	2.9	100
	47	3.43	10.8	3.3	250	2.17	6.7	3.3	100
	56	3.74	11.5	3.9	250	2.37	7.5	3.9	100
	68	4.12	12.3	4.5	250	2.61	8.3	4.5	100
	82	4.53	13.2	5.2	250	2.86	9.1	5.2	100
	100	5.0	14.0	6.0	250	3.2	10.1	6.0	100
	120	5.5	14.8	6.8	250	3.5	10.9	6.8	100
	150	6.1	15.8	8.0	250	3.9	11.8	8.0	100
	180	6.7	16.6	8.9	250	4.2	12.5	8.9	100
	220	7.4	17.4	10.1	250	4.7	13.4	10.1	100
	270	8.2	18.3	11.4	250	5.2	14.3	11.4	100
1 000	330	9.1	19.2	2.5	250	5.7	15.1	2.5	100
	390	9.9	19.9	2.9	250	6.2	15.8	2.9	100
	470	10.8	20.7	3.3	250	6.9	16.7	3.3	100
	560	11.8	21.4	3.9	250	7.5	17.5	3.9	100
	680	13.0	22.3	4.5	250	8.2	18.3	4.5	100
	820	14.3	23.1	5.2	250	9.1	19.2	5.2	100
	1 000	15.8	24.0	6.0	250	10.0	20.0	6.0	100
	1 200	17.3	24.8	6.8	250	11.0	20.8	6.8	100
	1 500	19.4	25.8	8.0	250	12.2	21.7	8.0	100
	1 800	21.2	26.6	8.9	250	13.4	22.5	8.9	100
	2 200	23.4	27.4	10.1	250	14.8	23.4	10.1	100
	2 700	26.0	28.3	11.4	250	16.4	24.3	11.4	100

TABLE I *(continued)*

		Rated dissipation, W							
		⩾ 0.25				0.125 & 0.100			
R_3 Ω	R_T Ω	U_1 V	D dB	Δ dB	P mW	U_1 V	D dB	Δ dB	P mW
10 000	3 300	28.7	29.2	2.5	250	18.2	25.2	2.5	100
	3 900	31.2	29.9	2.9	250	19.7	25.9	2.9	100
	4 700	34.3	30.8	3.3	250	21.7	26.7	3.3	100
	5 600	37.4	31.5	3.9	250	23.7	27.5	3.9	100
	6 800	41.2	32.3	4.5	250	26.1	28.3	4.5	100
	8 200	45.3	33.2	5.2	250	28.6	29.1	5.2	100
	10 000	50.0	34.0	6.0	250	32	30.1	6.0	100
	12 000	54.8	34.8	6.8	250	35	30.9	6.8	100
	15 000	61.2	35.8	8.0	250	39	31.8	8.0	100
	18 000	67.1	36.6	8.9	250	42	32.5	8.9	100
	22 000	74.2	37.4	10.1	250	47	33.4	10.1	100
	27 000	82.2	38.3	11.4	250	52	34.3	11.4	100
100 000	33 000	90.8	39.2	2.5	250	57	35.1	2.5	100
	39 000	98.7	40.0	2.9	250	62	35.8	2.9	100
	47 000	108	40.7	3.3	250	69	36.7	3.3	100
	56 000	118	41.5	3.9	250	75	37.5	3.9	100
	68 000	130	42.3	4.5	250	82	38.3	4.5	100
	82 000	143	43.1	5.2	250	91	39.2	5.2	100
	100 000	158	44.0	6.0	250	100	40.0	6.0	100
	120 000	173	44.8	6.8	250	110	40.8	6.8	100
	150 000	194	45.8	8.0	250	122	41.7	8.0	100
	180 000	212	46.5	8.9	250	134	42.5	8.9	100
	220 000	234	47.5	10.1	250	148	43.4	10.1	100
	270 000	250	48.0	11.4	232	164	44.3	11.4	100
	330 000	250	48.0	12.7	190	182	45.2	12.7	100
	390 000	250	48.0	13.8	160	198	45.9	13.8	100
	470 000	250	48.0	15.1	133	217	46.7	15.1	100
	560 000	250	48.0	16.4	112	237	47.5	16.4	100
	680 000	250	48.0	17.8	92	250	48.0	17.8	92
	820 000	250	48.0	19.3	76	250	48.0	19.3	76
	1.0 M	250	48.0	20.8	63	250	48.0	20.8	63
	1.2 M	250	48.0	22.3	52	250	48.0	22.3	52
	1.5 M	250	48.0	24.1	41.7	250	48.0	24.1	41.7
	1.8 M	250	48.0	25.6	34.7	250	48.0	25.6	34.7
	2.2 M	250	48.0	27.2	28.4	250	48.0	27.2	28.4
	2.7 M	250	48.0	28.9	23.2	250	48.0	28.9	23.2
	3.3 M	250	48.0	30.6	18.9	250	48.0	30.6	18.9
	3.9 M	250	48.0	32.0	16.0	250	48.0	32.0	16.0
	4.7 M	250	48.0	33.6	13.3	250	48.0	33.6	13.3
	5.6 M	250	48.0	35.1	11.2	250	48.0	35.1	11.2
	6.8 M	250	48.0	36.8	9.2	250	48.0	36.8	9.2
	8.2 M	250	48.0	38.4	7.6	250	48.0	38.4	7.6
	10 M	250	48.0	40.1	6.2	250	48.0	40.1	6.2
	12.M	250	48.0	41.7	5.2	250	48.0	41.7	5.2
	15 M	250	48.0	43.5	4.2	250	48.0	43.5	4.2
	18 M	250	48.0	45.2	3.5	250	48.0	45.2	3.5
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Doc : No LTD 14 (0014)

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Printed at Printwell Printers, Aligarh, India